AD-A116 572 GEORGIA INST OF TECH ATLANTA ENGINEERING EXPERIMENT --ETC F/G 17/8
SEEKER TARGET SYSTEM INVESTIGATION.(U)
APR 82 G R LOEFER, D E SCHMIEDER F30602-80-C-0233
UNCLASSIFIED GIT/EES-A-2692 RADC-TR-82-71 NL

1 OF 1
AD A
116572

END
DATE
FILMED
07-82
DTIC

(12)

AD A116572

RADC-TR-82-71
Final Technical Report
April 1982

SEEKER TARGET SYSTEM INVESTIGATION

Georgia Institute of Technology

Gene R. Loefer and David E. Schmieder

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

This report has been reviewed by the RADC Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be releasable to the general public, including foreign nations.

RADC-TR-82-71 has been reviewed and is approved for publication.

APPROVED:

CHARLES M. BLANK
Project Engineer

APPROVED: David C. Luke

DAVID C. LUKE, Colonel, USAF
Chief, Reliability & Compatibility Division

FOR THE COMMANDER: John P. Huss

JOHN P. HUSS
Acting Chief, Plans Office

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
RADC-TR-82-71

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
SEEKER TARGET SYSTEM INVESTIGATION

5. TYPE OF REPORT & PERIOD COVERED
Final Technical Report
07-08-80 - 10-07-81

6. PERFORMING ORG. REPORT NUMBER
A-2692

7. AUTHOR(s)
Gene R. Loefer
David E. Schmieder

8. CONTRACT OR GRANT NUMBER(s)
F30602-80-C-0233

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Georgia Institute of Technology
Engineering Experiment Station
Atlanta GA 30332

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
6474F
20640211

11. CONTROLLING OFFICE NAME AND ADDRESS
Rome Air Development Center (RBCM)
Griffiss AFB NY 13441

12. REPORT DATE
April 1982

13. NUMBER OF PAGES
36

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
ONRR
Georgia Institute of Technology
Atlanta GA 30332

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
N/A

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
Same

18. SUPPLEMENTARY NOTES
RADC Project Engineer: Charles M. Blank (RBCM)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Simulation
Hardware
Infrared
Electro-Optics
Lasers
Visible
Missile Seeker Testing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This report documents the design and construction of a target source simulation breadboard, the seeker target system (STS). The report describes system performance and provides instructions for system setup and operation. Also described and expressly stated are all the calculations required to operate the STS.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SUMMARY

This report documents the design, fabrication, and test of a seeker targeting system. The objective of this effort was to investigate and fabricate a target motion simulator and associated infrared, electro-optical and laser sources for implementation in the Electromagnetic Compatibility Analysis Facility (EMCAF) at the Rome Air Development Center. The effort resulted in a breadboard model to be utilized as a target simulator to exercise various guided bomb/missile seeker units while they are simultaneously being irradiated with high power RF energy. The breadboard model will be used in the EMCAF to determine the susceptibility of Air Force weapon systems to the electromagnetic environment in which they operate. The design in an intense electromagnetic environment, the physical size of the systems under test and the requirement that the system project a collimated image to the seeker. It was also constrained by stringent controls of such key characteristics as target angular size, angular rate, position and jitter. A primary goal of the breadboard design was to produce a system that would be as close to a fully operational simulator as possible. This goal has, in fact, been accomplished with the final design meeting or exceeding nearly all of the critical design goals.

Table of Contents

1.0 Introduction

This report is intended to document the detailed results of the design and construction of a target source simulation breadboard. The seeker target system (STS) is designed to be used to test infrared, laser, and electro-optical guided missiles in the Rome Air Development Center (RADC) anechoic test chamber. In this test a missile will be subjected to RF radiation to determine its electromagnetic interference (EMI) susceptibility. In particular, the tests will attempt to determine the conditions which cause loss of missile control as a function of target parameters. In these tests, the simulator will provide a target upon which to lock the missile seeker and control gimbal pointing angle and track rate. The objective of this effort is to validate the design concept through the construction of a breadboard system.

A primary goal of the breadboard design was to produce a system that would be as close to a fully operational simulator as possible. This goal has in fact been accomplished, with the final design meeting or exceeding nearly all critical design goals.

2.0 Design

The STS design was actually begun under a previous study contract (F30602-78-C-0120). Under this contract, simulator requirements were established after study of seeker characteristics, anechoic chamber restrictions and design cost/performance analyses. The result of this study was a conceptual design and cost estimate. Under the current contract, the conceptual design and design goals were fully reexamined, a detailed design was executed, and a breadboard simulator was constructed.

Electro-optic seekers and trackers are designed to operate against distant targets. Under such conditions objects are effectively located at infinity, i.e., light from each point on the object is collimated. The seeker optics therefore image targets in the system focal plane. If objects are too close, the image is located a significant distance behind the seeker focal plane and performance is seriously degraded. Therefore an E-O target simulator must present a collimated image to the seeker under test. A collimated image also simplifies calculation of effective irradiances at the seeker.

The STS produces a collimated target image by placing an E-O source in the focal plane of the primary mirror. In order to accurately measure the effects of RFI/EMI testing, the seeker must be operated against a moving target, whose position and velocity are known precisely. Apparent target motion is achieved in the STS by a circular rotation of an E-O source. A servo-controlled motor drives an off axis rotating aperture and both target position and rate are sensed through an optical shaft encoder. Various size pinholes can be fitted to the aperture to create different size targets. The apertures are illuminated by a variety of E-O sources which cover the spectrum from the visible to the far IR (8-14 μm wavelength). The energy from the sources is transferred via a rotating periscope which greatly reduces the required source diameter's dependence on scan angle.

3.0 Goals vs Actual Performance

At the end of the original study, a set of design goals was generated. During detailed design and breadboard construction, these goals were considered as if they were system specifications. The breadboard constructed and delivered meets or exceeds nearly all the critical design goals, as is shown by the measured performance summarized in Table I.

In nearly all cases, target scan angle and target angular subtense have the same effects on system configuration. These two quantities drive the focal plane periscope design. Combined with unvignetted spot size, they also determine the required primary mirror diameter. A compromise design of $\pm 1^{\circ}$ scan was reached. Small increases in scan angles would exact a heavy penalty in required mirror apertures, as well as less severe decreases in resolution. Larger target sizes would exact the same penalties as increased scan angles. In addition, larger target sizes would seriously complicate focal plane periscope design and would require custom EO sources or complex source optics.

The design goal for an unvignetted spot size of 4" at 24 feet (10.16 cm at 7.32 m) was to cover a minimum seeker aperture diameter of 2.5" (6.35 cm) plus allow working room. The system meets the minimum requirements at maximum range, but not the desired goal. However, workable spot sizes are achieved at more probable ranges.

Scan rate variability was specified as an absolute number with no qualifications. This number was derived from seeker track noise levels, and was intended to be applied to the minimum scan rate. This corresponds to a variability of 50% of the minimum scan rate. If applied to the maximum scan rate, this would indicate a 0.1% tolerence. This requirement was considered unnecessarily strict for the high rates. Instead a more reasonable value of $\pm$ 1% variability over the entire specified scan rate range was achieved with a servo-controlled motor. In addition, this provides a much better performance at the lower (and most critical) scan rates. Outside the specified range, a variability of $\pm$ 10% was observed.

Table I.

Characteristic	Goal	Design	Actual
Resolution	$\leq$1.0 mrad	$\leq$1.0 mrad ($\pm 1^{\circ}$ scan) $\leq$2.0 mrad	<0.1 mrad [4" (10.2cm) optics, full aperture]
Scan angle	$\pm 1^{\circ}$ with a Goal of $\pm 2^{\circ}$	$\pm 1^{\circ}$ all working specs $\pm 1.5^{\circ}$ relaxed requirements	same as design
Spot size	4" @ 24 ft. (10.2cm @ 7.32m)	2.5" @ 24 ft. (6.4cm @ 7.32m) 3.0" @ 21.8 ft. (7.6cm @ 6.64m) 4.0" @ 17.9 ft. (10.2cm @ 5.46m)	same as design
Max. target size	2.0°	0.5°	same as design
Min. target size	1.0 mrad	1.0 mrad	0.6 mrad
Target position accuracy	0.8 mrad	Est. 2.0 mrad	0.92 dynamic $\leq$0.1 static
Target position output accuracy	----	0.767 nominal	0.92 dynamic
Max. scan rate	30°/sec	30.7°/sec	same as design
Min. scan rate	1.2 mrad/sec	0.428 mrad/sec. w/ output 0.360 mrad/sec. w/o output	0.11 mrad/sec. all w/ output
Scan rate variability	0.6 mrad/sec. (i.e. 50% of Min. rate)	Max. 1% over entire range	$\pm$1% spec $\pm$10% elsewhere

Table I. (Cont.)

Characteristic	Goal	Design	Actual
Scan rate output	Digital	16 bit word, Elapsed time per quad	16 bit E.T. for one rev to 1/128 rev
Scan rate readout	Panel Meter	Motor rpm, 3 1/2 Digit display	same as design
Total weight	500 lbs. (227 kg)	500 lbs. (227 kg)	475 lbs. (216 kg) w/o covers 671 lbs. (305 kg) w/ covers
Irradiance (Max) 1 deg target 0.6 to 0.9 μm	8×10^{-5} w/cm^2	10^{-5}	7.7×10^{-6} w/cm^{2*}
0.4 to 0.7 μm	8×10^{-5} w/cm^2	10^{-5}	4.2×10^{-6} w/cm^{2*}
1.5 to 3.0 μm	10^{-7} w/cm^2	----	1.8×10^{-5} w/cm^2 (2.19 to 2.31 μm)
3.5 to 5.5 μm	4×10^{-7}	----	1.5×10^{-5} w/cm^2 (3.73 to 3.90 μm)
8.0 to 13.5 μm	10^{-9}	----	8.2×10^{-7} w/cm^2 (11.2 to 11.4 μm)

*measured from 1 mrad target; values corrected to 1 degree target for comparison.
Max. target size is 0.5 degrees.

The total system weight with the dust covers was slightly over the design goal. This was not considered a serious drawback, as the cover sections were each easily two man portable. The total weight less covers was 25 pounds (11.34 kg) under maximum design goal.

Maximum irradiances all exceeded the design goals except for the visible bands. However, direct observation determined that the images were extremely bright and should be perfectly adequate targets.

Target position accuracy was slightly worse than the design goal (15%) for a dynamic target but is a factor of 10 better in the static case. This indicates the major error source is in the focal plane motion, probably due to the accuracy of the drive gears. However, the gears used were the best available without resorting to exotic custom gears with long lead times and prices over $20K each.

All other goals including static resolution, minimum target size, scan rate dynamic range, scan rate outputs and IR irradiances exceed design goals.

4.0 Setup and Operation

4.1 Initial Setup Procedure, Figure 4.1.1

1. Assemble optical rails.
2. Mount focal plane assembly base plate.
3. Loosely mount focal plane assembly.
4. Loosely mount primary mirror, do not mount flat fold mirror at this time.
5. Adjust primary to focal plane distance and focal plane tilt.
6. Align image center to sight marks at flat mirror location (w/o flat).
7. Mount flat.

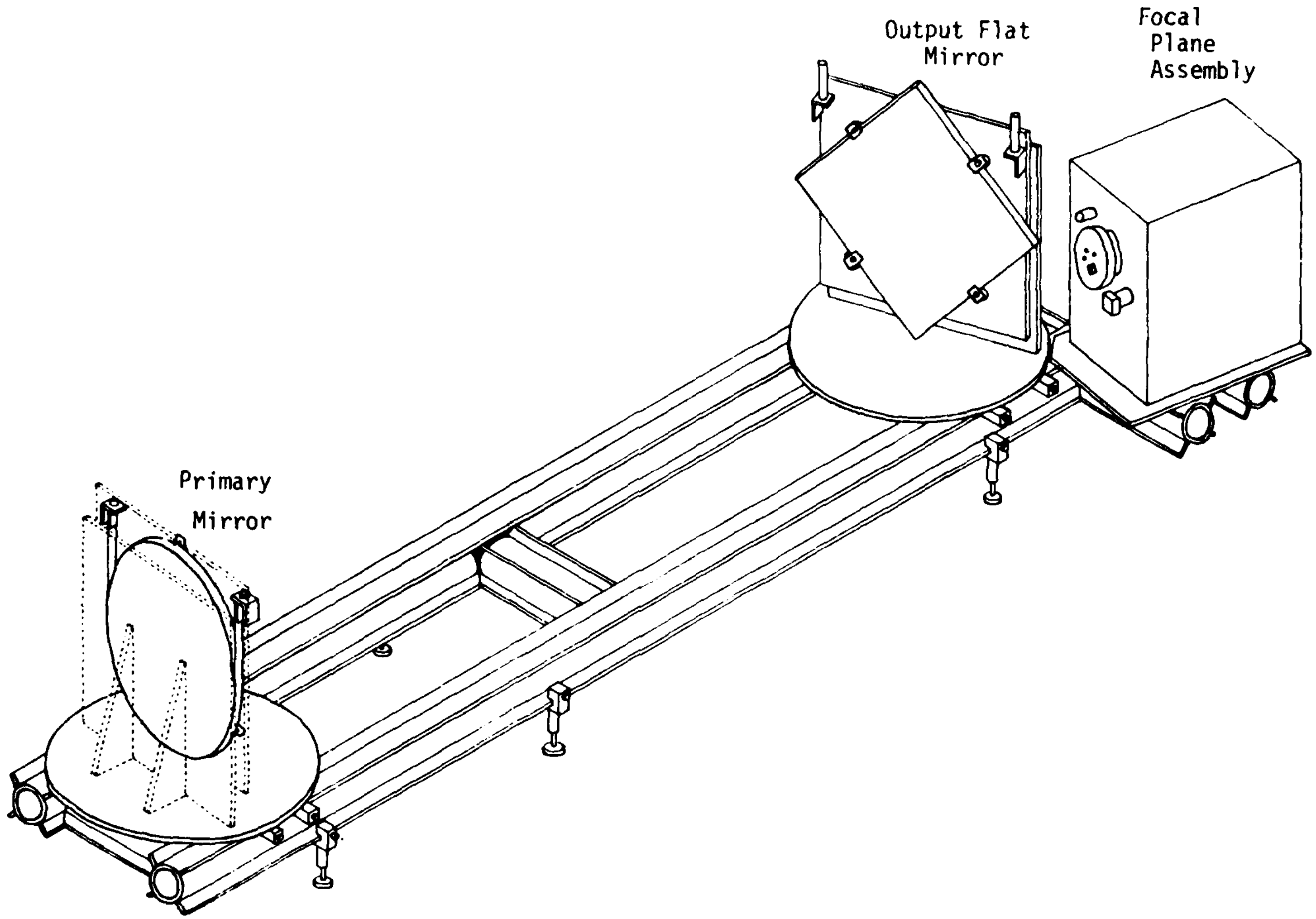


Figure 4.1.1. System Setup.

8. Install alignment scope in focal plane assembly.
9. Position crosshairs on seeker by moving flat. System is aligned optically.
10. Connect motor cable to electronic rack.
11. Connect encoder cable for digital outputs.
12. Connect arc lamp cable if required.
13. Connect blackbody cable if required.
14. Install dust covers, if desired.

4.2 Operation Procedure

1. Check system alignment. (See 4.1 and Hints 2-5,8).
2. Install alignment scope in focal plane assembly (FPA).
3. Position crosshairs on seeker by moving flat mirror.
4. Remove scope and install periscope mirror assembly.
5. Install proper target sized pinholes - be careful not to damage flat black coat.
6. Install light shield, if necessary.
7. Set scan angle.
8. Install appropriate source. See Source Installation.
9. Set motor control potentiometer for zero speed (full CCW).
10. Set arc lamp supply control to lowest setting (full CCW).
11. Turn on motor power for motor and encoder/decoder operation.
12. If used, turn on arc lamp supply power.
13. If used, turn on blackbody controller and set using calibration tables. This should give an approximate setting.

14. Acquire target with seeker.
15. For best accuracy, actual seeker response to blackbody input should be used. Used measured seeker responsivity.
16. Set motor speed to give desired scan rate. Operational setup complete.

4.3 Source Installation, Figure 4.3.1

4.3.1 Arc Lamp

1. Remove FPA cover.
2. Remove any other source and associated hardware.
3. Adjust shelf to top position.
4. Place arc lamp housing behind gear assembly. Three filter holding rods should be centered around periscope input aperture, with about 1/16" (2mm) clearance from the gear.
5. ND filters fit in rods between moveable collar and housing. Install if required.
6. Connect cables.
7. Replace FPA cover.

4.3.2 Blackbody

1. Remove FPA cover
2. Remove any other source and hardware
3. Adjust shelf to bottom position.
4. Mount ZnSe lens and holder. Lens end fits into periscope input aperture. Adjust holder so that it is concentric with the aperture.

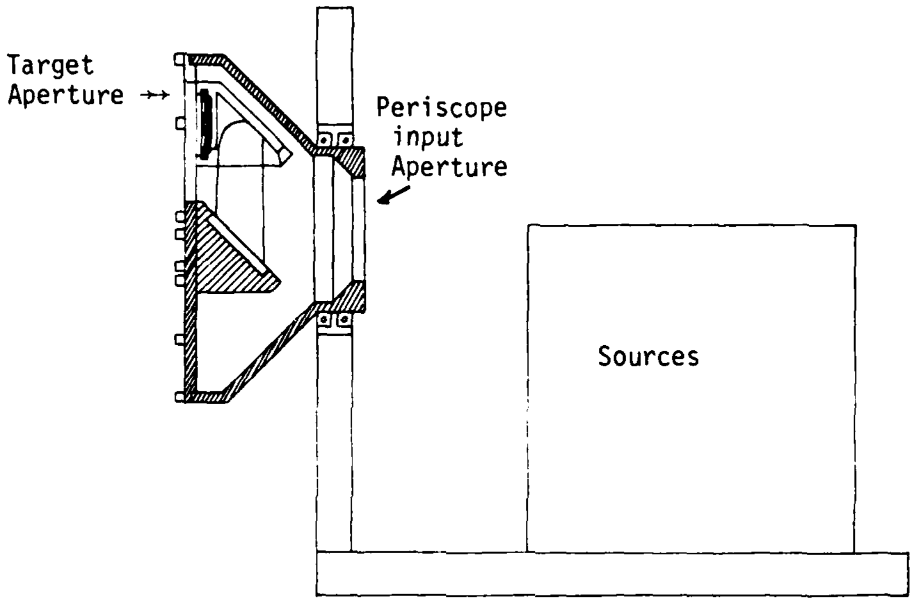


Figure 4.3.1. Focal plane assembly.

5. IR filters slide into slot at back of lens holder.
6. Connect cables.
7. For accurate temperature control, immerse thermocouple reference junction in $0^{o}C$ ice bath. See Blackbody Manual.

4.3.3 Laser

1. Remove FPA cover.
2. Remove other sources.
3. Adjust shelf to middle position.
4. Assemble laser according to manufacturer's instruction.
5. Replace cover.

4.4 Dust Covers

There are three large dust cover segments and one small cover for the focal plane assembly, Figure 4.4.1. The three large covers are labeled as follows:

Cover A: Largest cover, which covers the primary mirror end, left end when viewed from output side of flat. Open edge is straight. Cover A requires two people to handle.

Cover B: Center, U-shaped section, with output window. Requires bottom braces. Can be handled by one, but two is preferable.

Cover C: Left end cover goes over output flat and focal plane assembly. Can be handled by one.

4.4.1 Installation

1. Complete assembly of optics, rails and focal plane assembly.
2. Position assembly on chamber platform.
3. Place cover A over primary mirror end and note location of open edge.
4. Slide cover A back approximately 3 to 4 inches (8 to 10 cm).
5. Carefully slide cover C over rails from output flat end. Use extreme care as clearances are very tight. Also, be sure cables are kept clear during installation.
6. Locate cover B edge at spot determined in step 3.
7. Install angle braces at bottom edges of both openings of cover B.
8. Lift cover A up at both ends and locate edge of A in channel of B. Lower cover A.
9. Align edges of A in side channels.
10. Lock three handles and two catches. Handles should be adjusted to provide a firm alignment of the two pieces.
11. Repeat steps 8 through 10 for cover C.
12. Cover C is designed for easy access to output flat and focal plane assembly.

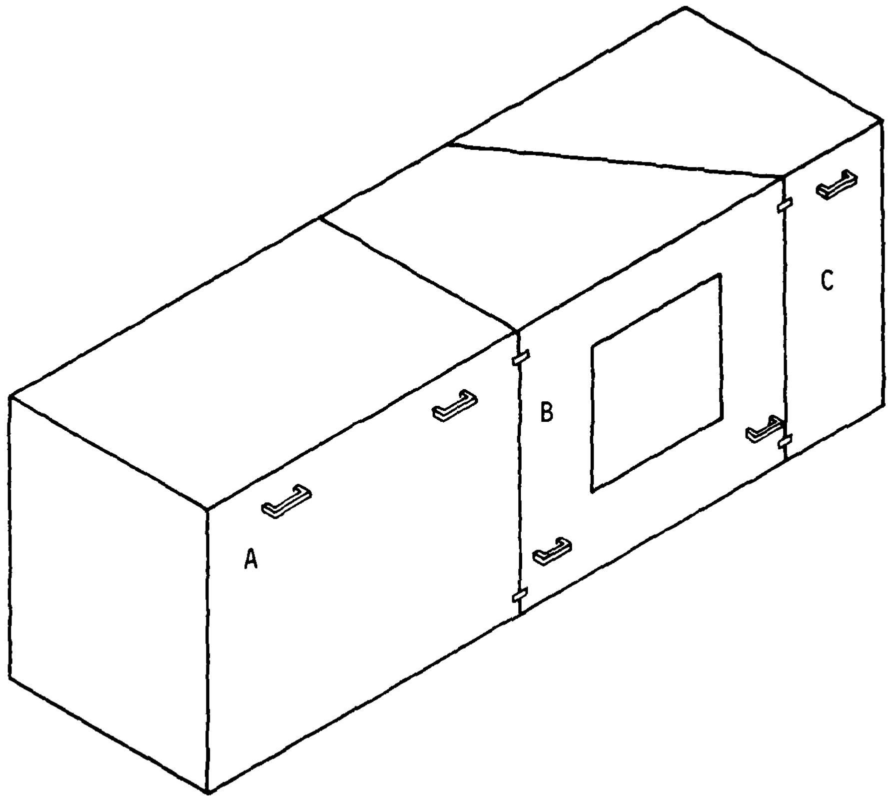


Figure 4.4.1. Dust covers

4.4.2 Removal

1. Release all latches and handles.
2. Remove cover C by lifting up, then away from B.
3. Lift both ends of cover A up, then away from cover B.
4. Remove cover B braces.
5. Slide cover B towards primary and remove when clear. Cover B may also be slid over output end, but extreme care should be used, as clearances are very tight. Also cables should be kept clear during cover B removal.

4.5 Warnings and Hints

1. Extreme care must be taken to avoid any contact with the reflective coatings on the main mirrors, as they are easily marred.
2. Assembly optical rails, using scribe marks and lettered codes. The only critical placement is the distance from the primary mirror to focal plane.
3. This distance should be 78.75" $\pm$ 0.25" (2.0m $\pm$ 0.6cm) from the center of the primary to the pinhole aperture plane. Since it is NOT recommended to place any measuring device against the mirror surface, the distance can be computed from the edge of the primary to its mount. The distance from the focal plane to a convenient point on the assembly base can be calculated. The primary to focal plane distance can be calculated and set with a tape measure. This is sufficient accuracy for a good focus. See Hint 8 for focusing procedures with an autocollimator. Loose insertion of the front locking screw on the focal plane assembly will facilitate later alignment.

4. Carriers on optical rails are sometimes difficult to remove or adjust. This can usually be alleviated by turning clamp screws as far in as they will go without forcing. Apply outward pressure on clamping feet as clamp screw is released.
5. Quick assessment of optical alignment can be done by eye throughout most of this system. The current location of the optical line of sight can be determined by looking into the system and changing the position of the eye until the images of the circular focal plane plate and the primary mirror are concentric. The accuracy of the alignment can be improved by moving backward or forward until the relative sizes of the images are nearly the same. The human eye and brain are very good at comparing nearly concentric images.
6. Large optics can be transported while still in mounts if extreme care is used. If possible, two persons should handle as the the combination is very heavy.
7. Light dust and small scratches in optical surfaces only affect appearance, with little or no effect on performance. Therefore it is better to leave optics a little dirty than risk more significant damage by cleaning too often. If plastic dust bags are used, care should be taken when installing or removing them from optics, as they may scratch optical surfaces.

8. To set focus using autocollimator.
   a. Set collimator to exact infinity focus (usually 100% compensation).
   b. Locate pinhole with collimator.
   c. Adjust focal plane assembly to primary distance until sharp image of pinhole is achieved.
   d. Primary is focused.
9. Proper alignment of blackbody, ZnSe lens and collimator cannot be determined visually by observing through aperture and focal plane periscope. The observations are misleading and should NOT be used to judge alignment. Alignment can only be checked by observing scan from seeker location to insure that no vignetting is occuring.

5.0 System Calculations

This section presents the equations which are necessary to operate the STS. Each section has a brief explanation of the origin and/or theory of each set of equations.

5.1 Target Motion

5.1.1 Target Angles vs Focal Plane Distances

The amplitude of target motion or scan angle is calculated easily from simple geometry, Figure 5.1.1.1. The focal plane distance, d, is defined as the distance of the pinhole center from the center of the focal plane plate. The scan angle, Θ_s, is the arctangent of d, divided by the primary focal length, f.

Figure 5.3.1. Unvignetted spot diameter.

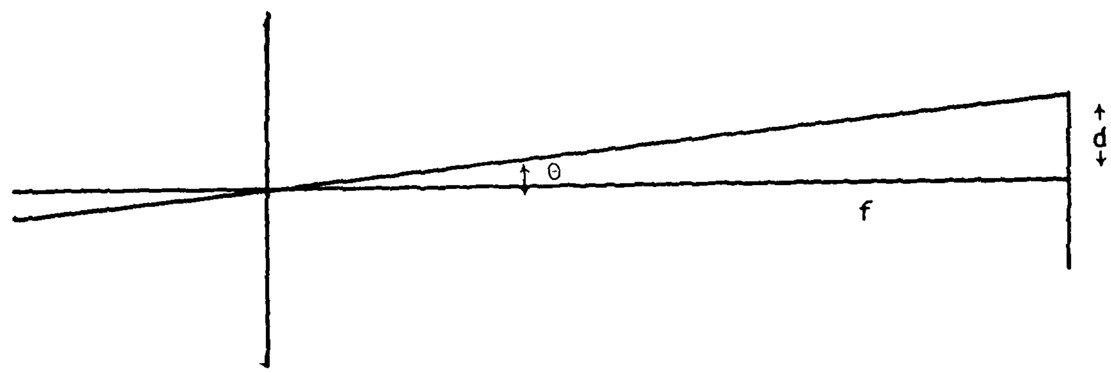


Figure 5.1.1.1. Focal plane distances vs. angle.

$$\Theta_s = \text{Atan } (d/f) \quad (1)$$

The scan angle is a radial measure, thus the total target motion is $\pm\ \Theta_s$.

It is very convenient to work in the metric system, since primary focal length of 78.75" equals exactly 2 meters. with the approximation

$$\tan \Theta \simeq \Theta \quad (2)$$

then equation 1 becomes

$$\Theta_s = d/f \quad (3)$$

Thus if d is in millimeters, and f is in meters, then Θ_s is in milliradians. More succinctly:

$$\Theta \text{ (mrad)} = \frac{d(\text{mm})}{2} \quad (4)$$

Equations 1,3 and 4 can also be used to calculate the target angular subtense, as all the relations are exactly the same.

Two conversion factors which are helpful to remember this process are:

1 inch = 25.4 mm

1 deg = 17.45 mrad.

5.1.2 Target Velocity vs Motor Speed

The three digit display on the STS indicates the motor speed in thousands of rpm (i.e. a meter reading of .634 = 634 rpm, 1.21 = 1210 rpm). This motor drives the focal plane through a set of gears, with the focal plane running slower than the motor by a factor of 25.71:1. The target velocity is defined as the tangential velocity of the target in its circular scan. Thus the target velocity, V, is a function of both the angular rate of rotation and the target scan angle, Θ_s.

$$V_T(\mathrm{deg/s}) = \frac{2\pi\ V_m(\mathrm{rpm})\ \Theta_s(\mathrm{deg})}{G\ 60(\mathrm{Hz/rpm})} \tag{5}$$

$$G = \text{gear ratio} = \frac{120\times198}{21\times44} = 25.71 \tag{6}$$

Θ_s = scan angle; V_T is in same units as Θ_s per second.
V_m = motor velocity

Other convenient formulas:

$$V_m(\mathrm{rpm}) = \frac{V_T(\mathrm{deg/s})\ G\ 60}{2\pi\ \Theta_s(\mathrm{deg})} \tag{7a}$$

$$V_m(\mathrm{rpm}) = \frac{V_T(\mathrm{deg/s})\ G}{6\ \Theta_s(\mathrm{rad})} \tag{7b}$$

$$= \frac{V_T(\mathrm{rad/s})\ 180\times60}{\pi^2\ \Theta_s(\mathrm{deg})} \tag{7c}$$

$$= \frac{V_T(\mathrm{mrad/s})\ 14.07}{\Theta_s(\mathrm{deg})} \tag{7d}$$

5.1.3 Target Position vs Counts

As part of the STS electronics rack, there are two digital outputs generated by the STS. The first is a 16 bit word which contains the target position with respect to the zero mark. This mark can be referenced to any particular physical orientation by loosening the set screw on the gear which drives the optical shaft encoder. The encoder can then be turned independently of the focal plane gears to align the physical and optical zero marks. The set screw is then tightened to maintain this reference.

The encoder is 13-bit serial with a zero reference. The STS electronics maintains an up/down count of the serial pulse string until reset by the zero reference mark. If the output counts down, the motor should be reversed. This is accomplished by swapping the two leads on the back of the motor with each other, then swapping the two leads on the front with each other. The fraction of a revolution from the zero mark is

$$\varepsilon = \frac{8192}{\mathrm{PCNTS}} \tag{8a}$$

PCNTS = position counts

$$P_T = 2\pi\varepsilon \quad \text{(radians)} \tag{8b}$$

$$= 360\varepsilon \quad \text{(degrees)} \tag{8c}$$

5.1.4 Target Velocity vs Elapsed Time

The second digital output is elapsed time. The elapsed time is for a fraction of a revolution which is hardware selectable from once per revolution to 128 times per revolution. Each reset pulse triggers a counter on a 2KHz clock which provides a number of counts, ECNTS, proportional to the elapsed time over that interval.

The velocity of the target can then be calculated by

$$V_T(\text{deg/s}) = \frac{2\pi\ f_c\ \Theta_s(\text{deg})}{\text{ECNTS}\ Q} \tag{9}$$

f_c = clock freq = 2000 $\sec^{-1}$

Q = # updates per revolution (1-128)

ECNTS = output counts

5.2 Irradiance

5.2.1 Planck's Law

Planck's Law describes the spectral radiant emittance of a perfect blackbody radiator as a function of wavelength and temperature.

$$W_\lambda(\lambda,T) = \frac{C_1}{\lambda^5(e^{C_2/\lambda T}-1)} \tag{10}$$

where C_1 = 37405 $W\mu m^4/cm^2$

C_2 = 14387.9 μm °K

when T = blackbody temperature is in degrees K

λ = wavelength in μm

W = spectral radiant emittance $W/cm^2/\mu m$

One must remember that the blackbody calibration curve in the blackbody operating manual provided with the STS is in degrees centigrade and that

$$T(^oK) = T\ (^oC) + 273 \qquad (11)$$

To find the total radiant emittance, one usually approximates a system's spectral transmittance by a rectangular bandpass with limits at the half-power wavelengths. The radiant emittance is given by

$$W = \int_{\lambda_1}^{\lambda_2} W\ (\lambda, T)\ d \qquad (12)$$

where W is in W/cm^2

λ_1, λ_2 = Band limits; usually half power points.

5.2.2 Blackbody Irradiance

For any seeker which falls within the unvignetted spot, the irradiance at the seeker dome is independent of range (up to spot limits, see Sec 5.3). The effective irradiance,

$$H_{eff} = \tau_o \tau_f \left(\frac{\Theta}{2}\right)^2 W \qquad (13)$$

where τ_o = transmission of collimator optics
= 0.92 without ZnSe lens
= 0.75 with ZnSe lens

τ_f = peak transmission of filter, Table II.

W = radiant emittance for blackbody over filter bandpass. (λ_1 to λ_2)

Θ = target angular subtense (radians)

H_{eff} is in W/cm^2.

5.2.3 Arc Lamp Irradiance

The arc lamp source can be treated as a blackbody radiator, after the diffusing glass and lamp geometry have been taken into account. The equivalent blackbody temperature is given by

$$T(^oK) = 1347 \quad V^{0.3319} \qquad (14)$$

Where V is the arc lamp supply voltage reading. The effective irradiance is then given by

$$H_{eff} = \frac{\Theta^2 W 10^{-Nd}}{4493} \qquad (15)$$

Table II. STS filters

Center λ (μm)	Bandpass Limits (μm) λ_1	λ_2	Transmission (τ_f)
For 1.5 to 3.0 μm			
2.24	2.19	2.31	0.59
For 3.5 to 5.5 μm			
3.82	3.73	3.90	0.62
For 8.0 to 13.5 μm			
11.32	11.17	11.40	0.52

Θ = target angular subtense (radians)

W = radiant emittance for temperature over desired spectral range.

Nd = neutral density filter optical density for no filter Nd = 0.0, i.e. $10^{-0} = 1.0$

This formula is good only to about 1.1 μm. Beyond this point, a relative transmission factor must be measured and included to account for the increase of opacity with wavelength of the diffusing glass and coating.

5.2.4 Laser Irradiance

The effective irradiance for a laser can be calculated if the effective radiant emittance, W_{laser}, of the diffuse laser source is known. It is given by:

$$H_{eff} = \tau_o \left(\frac{\Theta}{2}\right)^2 W_{laser} \qquad (16)$$

Where $\tau_o = 0.92$

Θ = target angular subtense

5.3 Unvignetted Spot Diameter

In order to use the irradiance equations of the previous section, the seeker must be completely inside the converging cone of collimated light, Figure 5.3.1. Figure 5.3.2 defines some of the parameters which determine the spot diameter, D_s.

$$D_s = D_c - 2s \tan \Theta \tag{17a}$$

$$\Theta = \Theta_s + \Theta_T/2 \tag{17b}$$

$$S = C+E$$

$$E = \sqrt{(R+A)^2 + B^2} \tag{17d}$$

D_c = diameter of collimator mirror = 16 in. = 41 cm

Θ_S = scan half angle

Θ_T = target angular subtense

S = total distance collimater to seeker

C = primary to output flat distance = 72 in. = 1.8m

A = distance from front of stage to output mirror center

B = distance from antenna centerline to output mirror center

R = distance from front of stage to seeker aperture

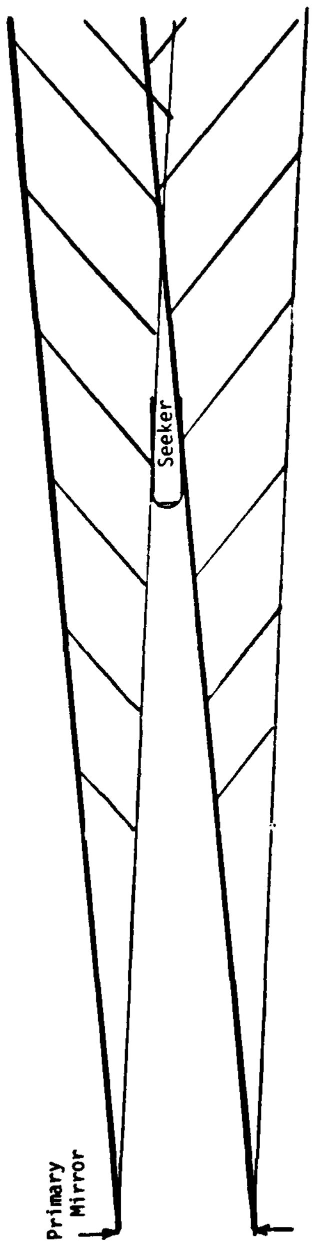
Several other convenient formulae:

$$S = \frac{D_c - D_s}{2 \tan} \tag{18}$$

$$\Theta = \text{Atan} \frac{D_c - D_s}{2S} \tag{19}$$

$$\phi = \text{Atan} \frac{B}{R+A} \tag{20}$$

ϕ = angle between centerline and line of sight to STS output mirror


Seeker
Primary Mirror

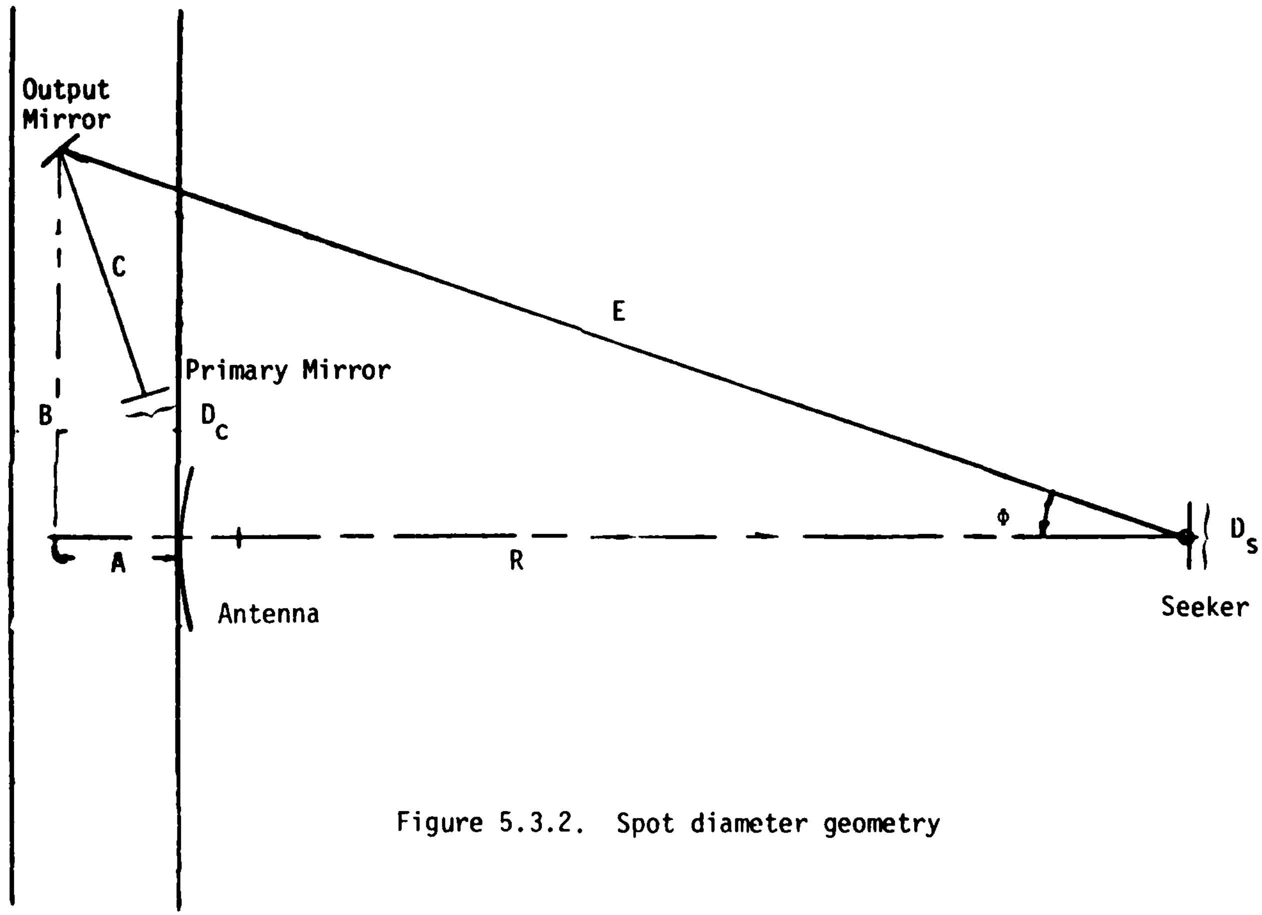


Figure 5.3.2. Spot diameter geometry

MISSION
of
Rome Air Development Center

RADC plans and executes research, development, test and selected acquisition programs in support of Command, Control Communications and Intelligence (C^3I) activities. Technical and engineering support within areas of technical competence is provided to ESD Program Offices (POs) and other ESD elements. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.

FILMED

7-8